Distribution System Infrastructure

Quick Review – What Is a Public Water System?

"…at least 15 service connections or regularly serves at least 25 individuals"
(Source: SDWA)

PWS Type	Data	Population Served					
		25-500	501-3,300	3,301-10,000	10,001-100,000	>100,000	Grand Total
CWS	Number of Systems	30,417	14,394	4,686	3,505	361	53,363
	Total Population Served	5,010,834	20,261,508	27,201,137	98,706,485	122,149,436	273,329,400
NTNCWS	Number of Systems	16,785	2,786	97	16	2	19,686
	Total Population Served	2,327,575	2,772,334	506,124	412,463	279,846	6,298,342
TNCWS	Number of Systems	85,366	2,657	96	29	4	88,152
	Total Population Served	7,315,647	2,602,706	528,624	619,248	12,269,000	23,335,225
Number of Systems		132,568	19,837	4,879	3,550	367	161,201
Total Population Served		14,654,056	25,636,548	28,235,885	99,738,196	134,698,282	302,962,967

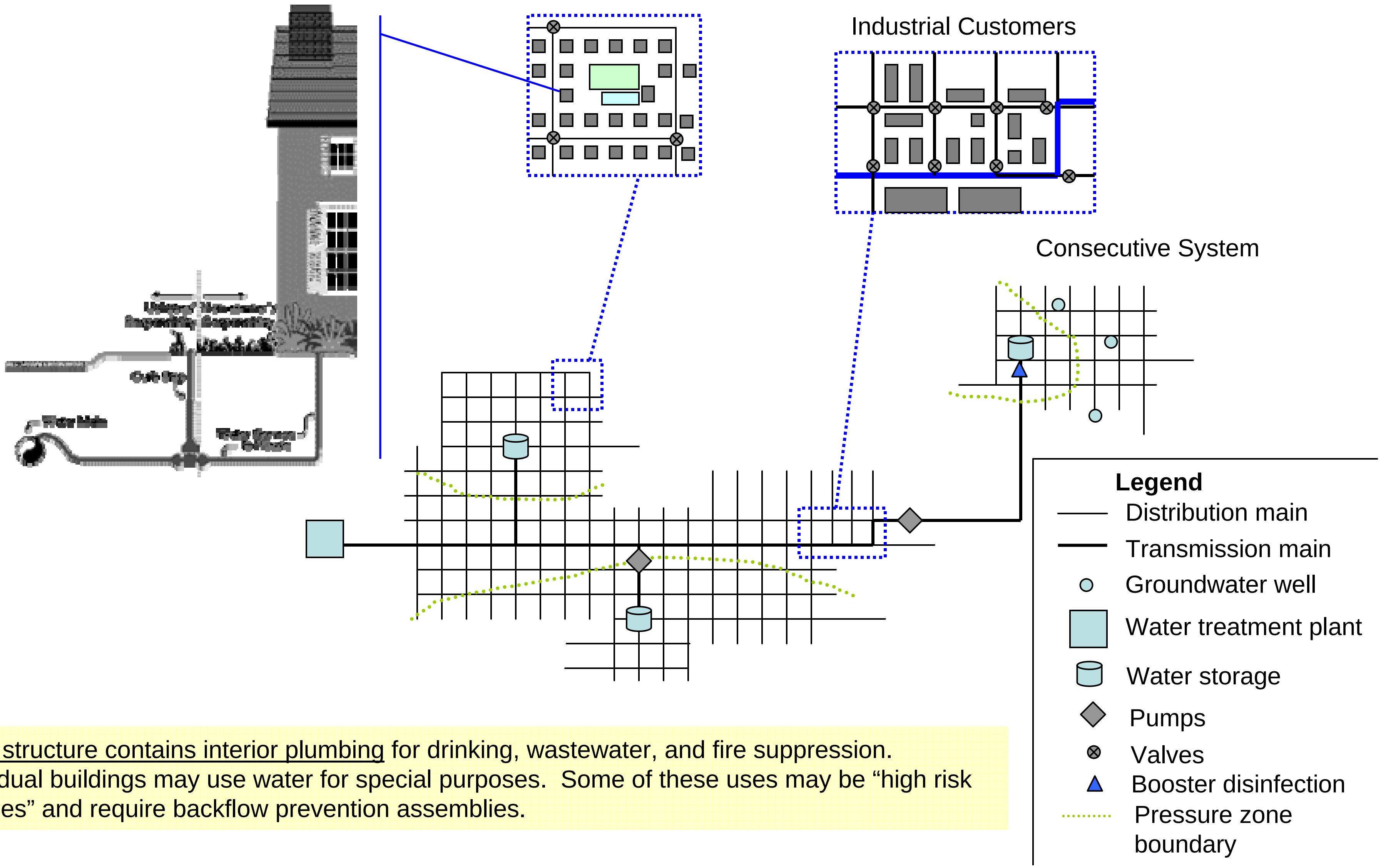
Source: Safe Drinking Water Information System, 4th Quarter 2003, EPA, 2004

What is a PWS “Distribution System”?

- A water system is defined by statute to include collection, treatment, <u>storage and distribution facilities under the control of the operator of such system</u>. (Source: SDWA §1401(4)(A)(i))
- What “storage and distribution facilities” are varies as a function of system type and size.
- The following schematics illustrate some similarities and differences.

Community Water System

e.g., municipality, public service authority, wholesale water provider



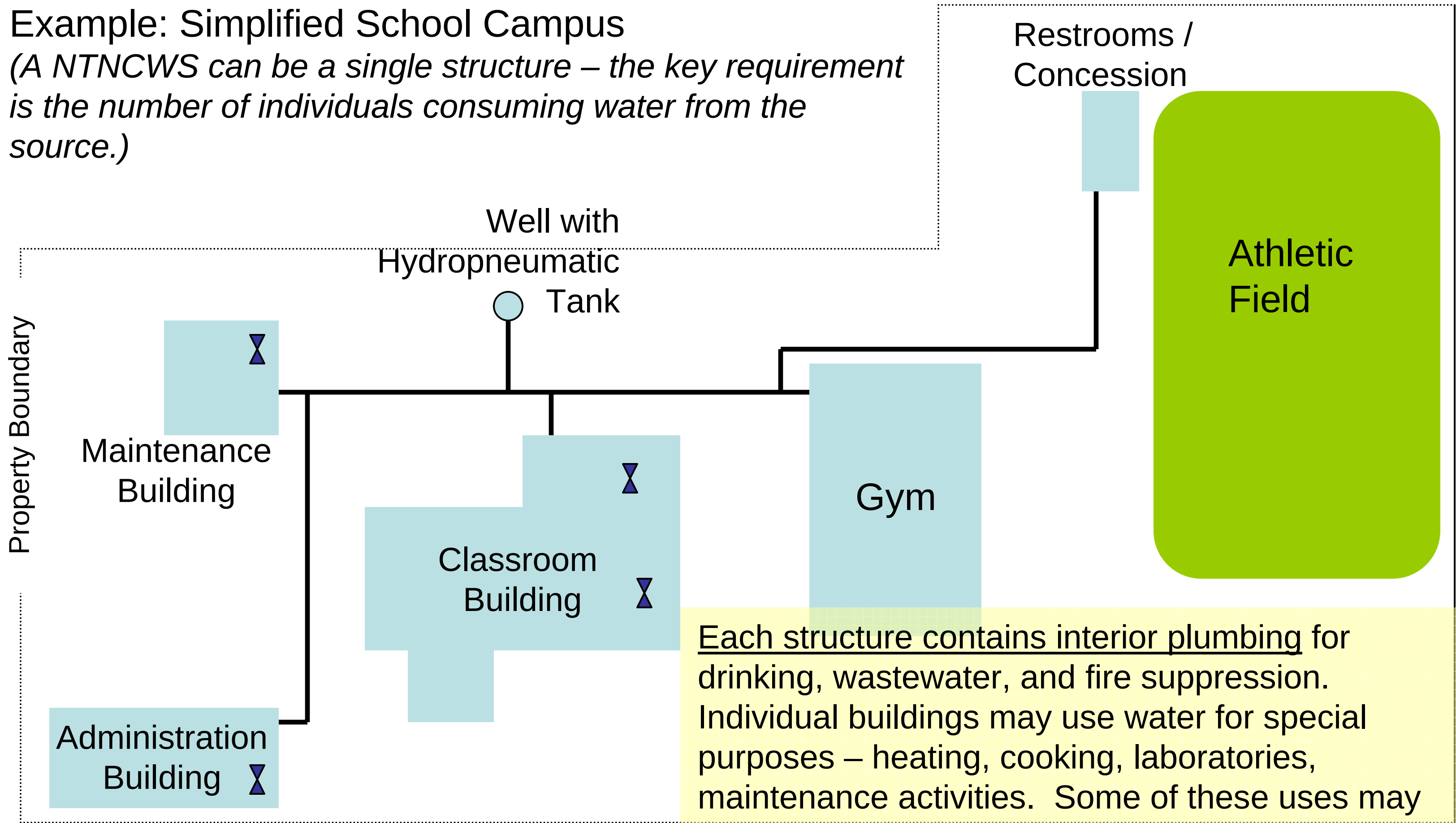
<u>Each structure contains interior plumbing</u> for drinking, wastewater, and fire suppression. Individual buildings may use water for special purposes. Some of these uses may be “high risk facilities” and require backflow prevention assemblies.

Non-Transient Noncommunity Water System

e.g., factory, church, school

Example: Simplified School Campus

(A NTNCWS can be a single structure – the key requirement is the number of individuals consuming water from the source.)

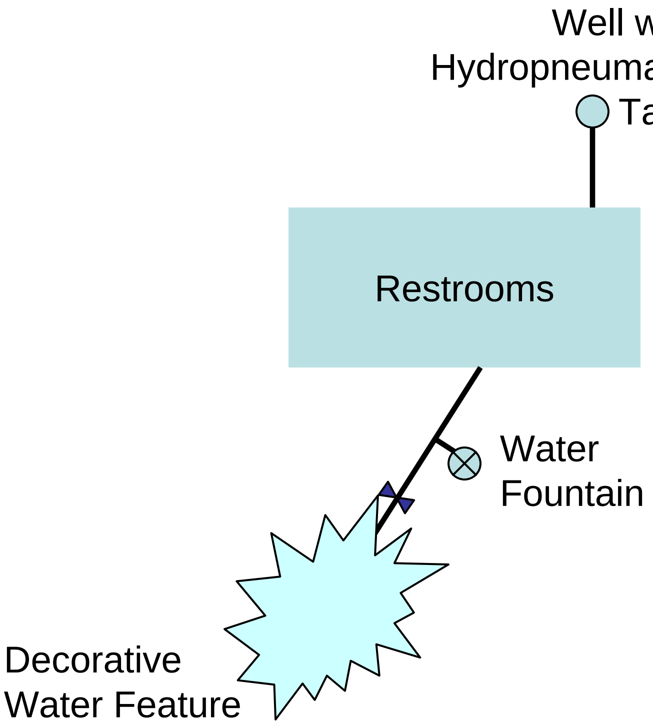


<u>Each structure contains interior plumbing</u> for drinking, wastewater, and fire suppression. Individual buildings may use water for special purposes – heating, cooking, laboratories, maintenance activities. Some of these uses may require backflow prevention assemblies.

Transient Noncommunity Water System

e.g., gas station, restaurant, highway rest area

Example: Basic Highway Rest Area
(A TNCWS can be a single structure or even no structure at all – the key requirement is the number of individuals consuming water from the source.)



<u>Structure(s) contain interior plumbing</u> for drinking, wastewater, and fire suppression. Individual buildings may use water for special purposes, such as cooking in a restaurant. Some of these uses may require backflow prevention assemblies.

Photos courtesy of Michigan DOH.

Physical Elements

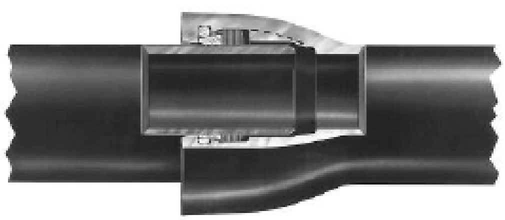
- Pipes
  - Transmission mains
  - Distribution piping
    - Meters and service line connections
- Fire Hydrants
- Storage
  - Steel, concrete, composite, other
  - In-ground, at grade, or elevated
- Pumps
- Controls
  - Either manual or SCADA (supervisory control and data acquisition systems) control system to operate pumps, etc.
  - Valves (multiple types-too numerous to describe)
  - Backflow prevention devices
- Monitoring Equipment
  - Pressure
  - Flow
  - Water quality
    - chlorine residual, pH, temperature, corrosion control (e.g. alkalinity or phosphate)

Pipes

Pipes	System Service Population								
	≤ 100	101-500	501-3,300	3,301-10,000	10,001-50,000	50,001-100,000	100,001-500,000	> 500,000	Average
Miles of Pipe in Place	1	4	28	85	232	395	579	2414	39
Service Connections per Mile	57	58	49	55	65	68	59	64	55
Average Annual Pipe Replaced in Past 5 Years (miles)	0	0	1	4	5	7	20	65	1
Average Annual Pipe Replaced in Past 5 Years - Average Cost Per Mile (1,000s)	$45	$107	$129	$222	$252	$386	$481	$1,719	$163

Source: Community Water System Survey, EPA, 2000

AMERICAN Fastite® Joint with Fast-Grip® Gasket, 4"-30"



Graphics courtesy of ACIPCO.

National Round-Up - Pipes

System Size (Pop Served)	Percent of Pipe per System by Age Class (Yrs)		
	< 40	40 - 80	> 80
< 100	90.6	9.4	0.1
101-500	88.3	11.7	0.1
501-3300	85.7	13.3	1.0
3300-10,000	84.3	12.9	2.8
10-50,000	81.4	15.3	3.4
50-100,000	70.2	23.4	6.4
100,000-500,000	60.9	29.7	9.4
500,000 +	56.3	34.4	9.2
Overall	78.0	18.0	4.0

Source: Community Water System Survey, EPA, 2000

System Size (Pop Served)	Average Miles of Pipe per System by Diameter (Inches)		
	< 6	6-10	> 10
< 100	1.1	0.1	0.0
101-500	3.4	0.5	0.1
501-3300	23.9	3.0	0.7
3300-10,000	60.8	18.0	4.5
10-50,000	121.4	78.0	31.1
50-100,000	141.6	121.6	78.7
100,000-500,000	259.9	181.8	139.5
500,000 +	819.0	915.7	684
Overall	23.7	9.9	4.6

Pipe Material	Percent of Piping	Pipe Material	Percent of Piping
Asbestos cement	15%	Ductile iron, cement lined	20%
Cast iron, unlined	14%	Polyethylene	1%
Cast iron-cement lined	14%	PVC	17%
Concrete pressure	2%	Steel	4%
Ductile iron, unlined	4%	Other	6%

Source: WaterStats, AWWA, 2002

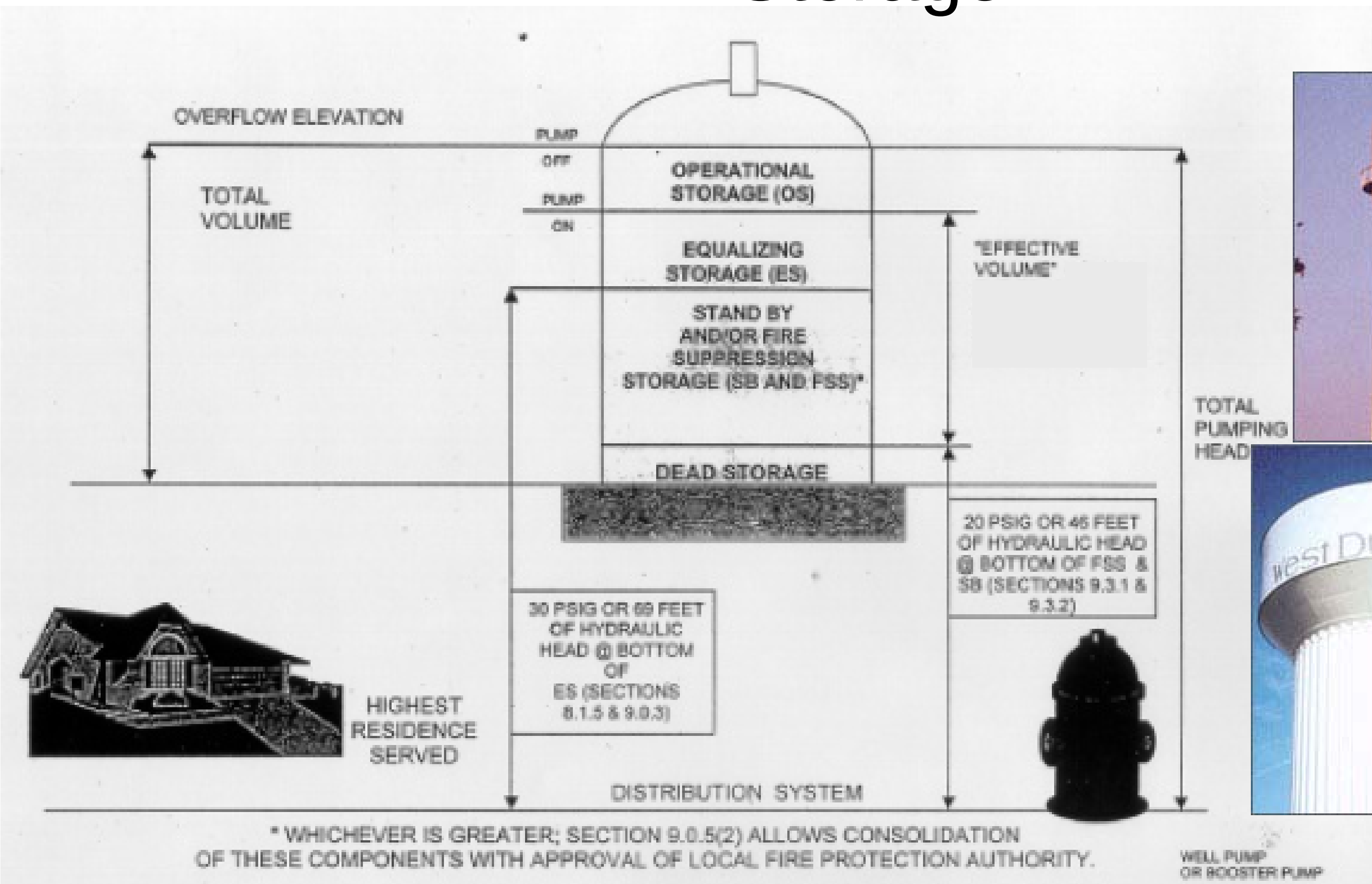
Materials and Conditions Impact Useful Life

MATERIAL	JOINT	Corrosion Protection INTERIOR	Corrosion Protection EXTERIOR	1900's	1910's	1920's	1930's	1940's	1950's	1960's	1970's	1980's	1990's
Steel	Welded	None	None										
Steel	Welded	Cement	None										
Cast Iron (pit cast)	Lead	None	None										
Cast Iron	Lead	None	None										
Cast Iron	Lead	Cement	None										
Cast Iron	Leadite	None	None										
Cast Iron	Leadite	Cement	None										
Cast Iron	Rubber	Cement	None										
Ductile Iron	Rubber	Cement	None										
Ductile Iron	Rubber	Cement	PE Encasement										
Asbestos Cement	Rubber	Material	Material										
Reinforced Conc. (RCP)	Rubber	Material	Material										
Prestressed Conc. (PCCP)	Rubber	Material	Material										
Polyvinyl Chloride	Rubber	Material	Material										
High Density Polyethylene	Fused	Material	Material										
Molecularly Oriented PVC	Rubber	Material	Material										

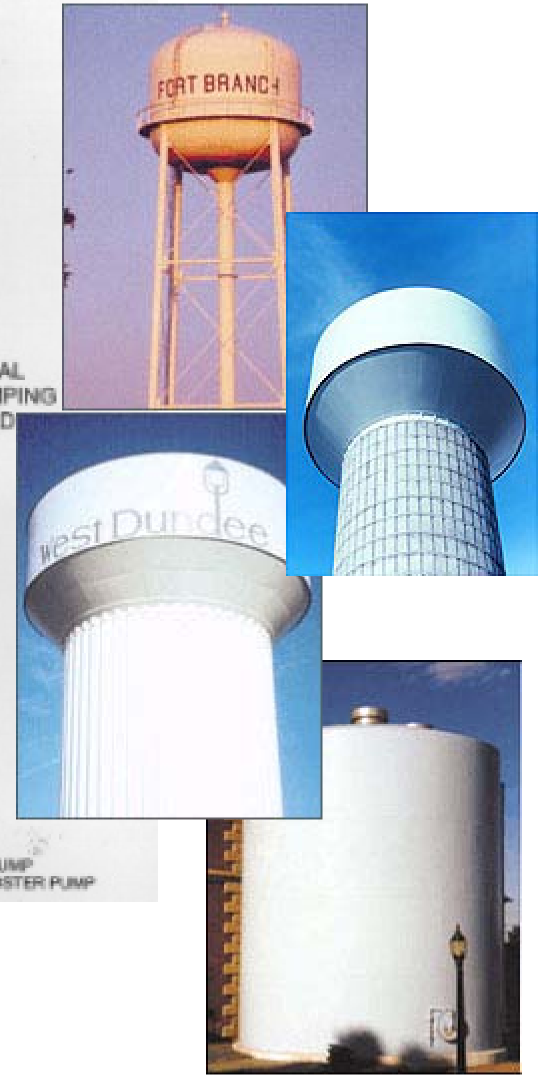
Commercially Available | Predominantly In Use

Source: Deteriorating Buried Infrastructure Management Challenges And Strategies, AWWS Co., 2002

Storage



Source: Deteriorating Buried Infrastructure Management Challenges And Strategies, AWWS Co., 2002



Photos courtesy of Pittsburg Tank and Tower Co.

National Round-Up - Storage

Storage Facility Inventory by System Size

Storage Facilities Within Distribution System	System Service Population								
	≤ 100	101-500	501-3,300	3,301-10,000	10,001-50,000	50,001-100,000	100,001-500,000	> 500,000	Average
Total Storage Capacity (MG)	0.06	0.29	0.32	1.29	5.52	17.64	42.84	222.13	1.70
Confidence Interval	0.04	0.41	0.05	0.18	0.90	3.69	9.90	36.96	0.22

Source: Community Water System Survey, EPA, 2000

Storage Facility Construction

Facility	Average percentage
Elevated	18%
Standpipes	10%
Metal Ground Storage	33%
Reinforced	12%
Wirewound	7%
Tendons	1%
Composite	1%
Basins	11%
Other	8%

Source: WaterStats, AWWA, 2002

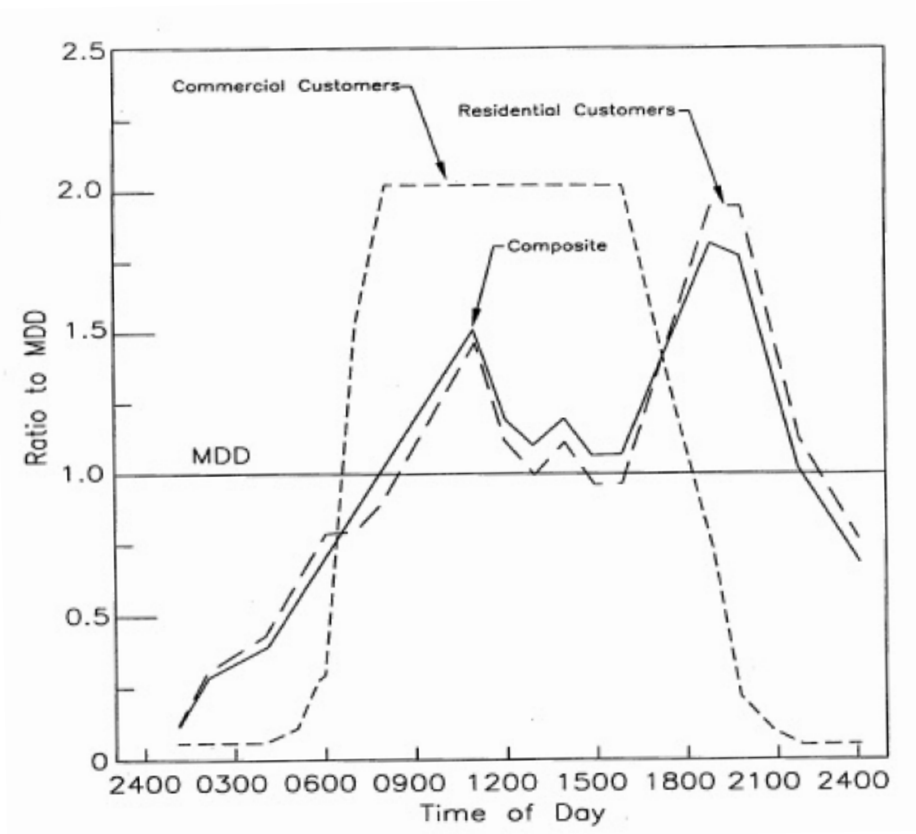
CWS – Scale

Attribute	Small CWS	City	Large Metro
Population (persons served)	501 – 3,300	100,000 – 500,000	>500,000
Example	Groveland Community Services District, CA	Newport News, VA	Boston, MA
Distributed Volume (Million Gallons Per Day)	2.8	45	220
Number of Storage Facilities (not including clearwells)	5	10	85
Miles of Pipe (miles)	70	1,600	6,300
Distribution System Staff (FTEs)	10	124	350
Distribution System as % of Capital Budget[1]	20%	2%	50%
Distribution System Annual O&M Budget	$1 M	$8.3 M	$40 M

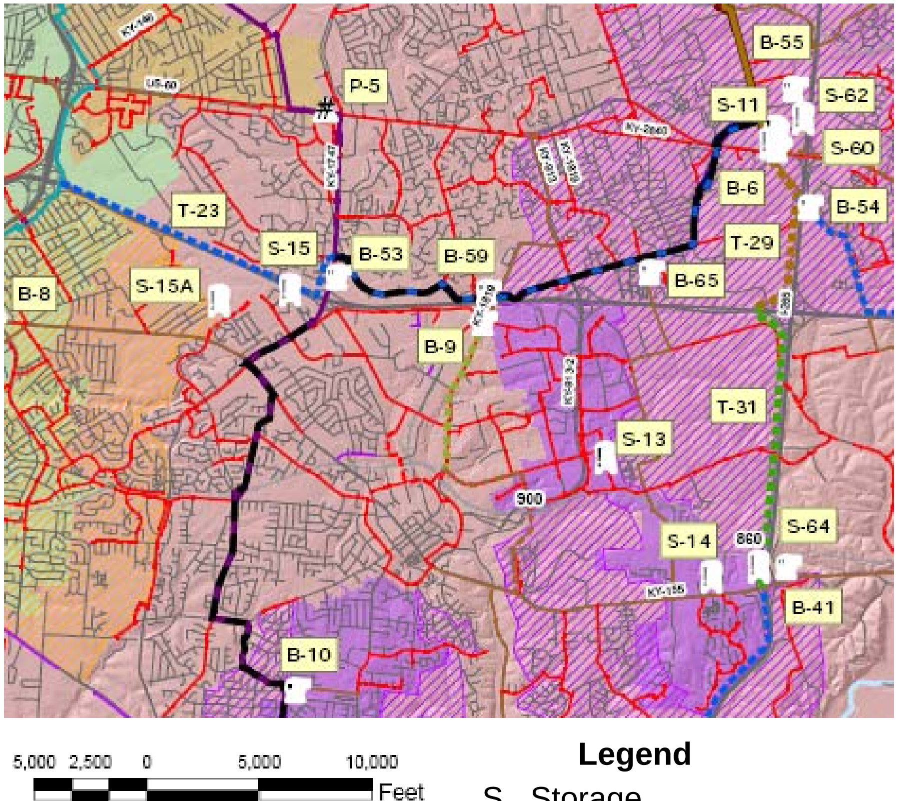
Note: [1] Capital costs are limited to those within the PWS budget and do not include investments made by developers, wholesale accounts, etc.

Factors Affecting Distribution System Design and Operation

- Physical Setting
  - Topography
  - Geologic setting
  - Weather patterns
- Design Goals
  - Fire flows
  - Per capita demand and peaking factors
  - Redundancy / reliability
- Community / System Objectives
  - Customer expectations (e.g., water outages)
  - Water quality
  - Population growth
  - Economic development
- Regulatory Requirements
  - Federal SDWA requirements
  - State requirements
  - Local ordinances
- Non-Regulatory Requirements
  - Insurance requirements for fire flows



One Example Constraint - Topography

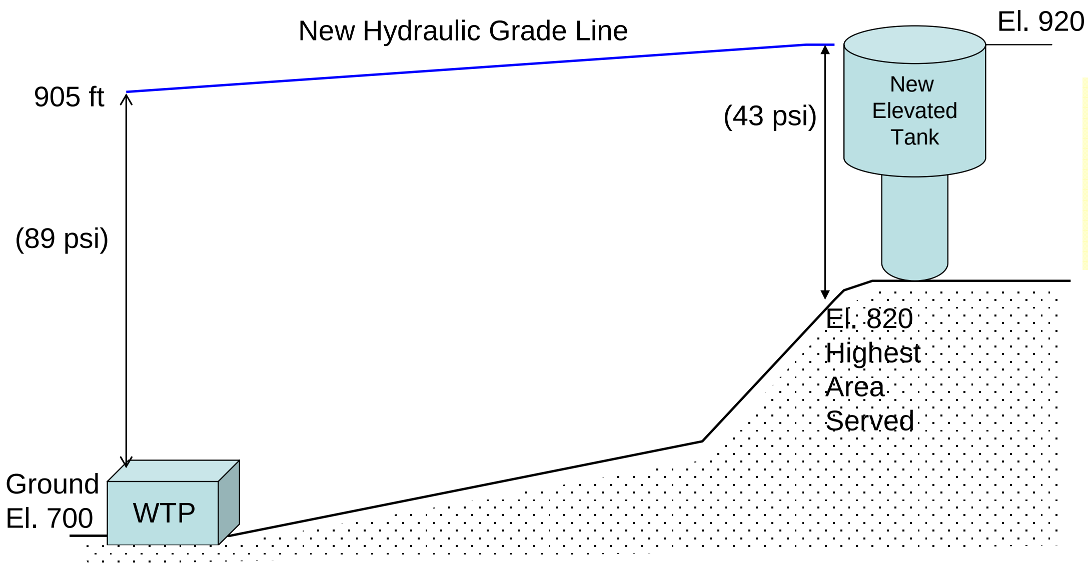


Legend

S Storage
B Booster Pump
P Pressure Reducing Station
T Transmission Main

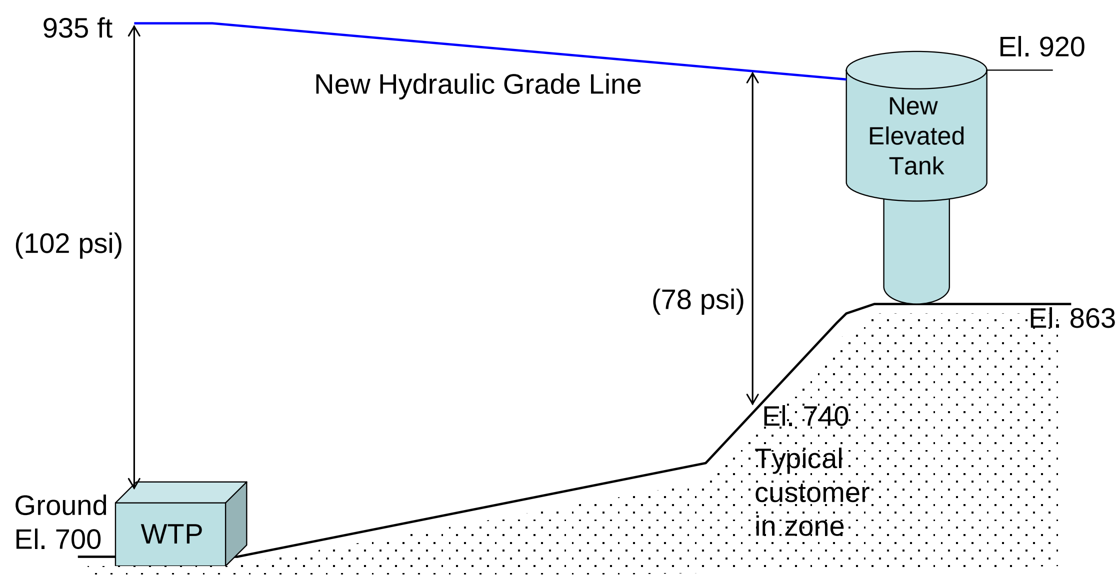
Approximately 6 square mile section of a CWS pressure zone map.

- This section (approx. 6 sq. m.)
  - 6 pressure zones
  - 8 storage facilities
  - 8 pump stations
  - 3 proposed transmission mains
- Overall System
  - Approximately 400 square mile service area
  - 2 water treatment plants
  - 3,500 miles of main
  - >40 storage facilities
  - >40 booster pumps
  - 24 pressure reducing stations
  - 5 consecutive systems



Pumps off at WTP, new elevated tank, piping improvements to tank

3 pumps running at WTP, new elevated tank, piping improvements to tank



Managing Distribution System Assets

- Capital Investment
  - Construction by PWS
  - Construction by “Developer”
  - Acquisition
- Operation and Maintenance
  - Maintaining adequate supply at appropriate pressure is distributed from available sources of supply
  - Repairs
  - Condition assessment
  - Storage facility inspection, cleaning, painting
  - Maintenance of mechanical systems
  - Valve exercising
  - Flushing
  - Fire flow testing

Capital Investment Process

- Long-Range Planning
- Capital Improvements Plan
- Financial Planning
- Preliminary & Final Design
- Procurement
  - Develop Bid Specifications
  - Competitive Bid
  - Bonding
- Construction
- Inspection
- Acceptance
- Warranty

Development of property requires installation of utilities to PWS specifications.

Acquisition typically involves inspection and agreement on terms for transfer of ownership.

Financing Methods

Pay-As-You-Go ………………………	51.7 %
Revenue bonds………………………	46.1 %
State Revolving Fund (SRF) loans …	38.3 %
General obligation bonds ……………	28.8 %
Private activity bonds ……..…………	0.8 %

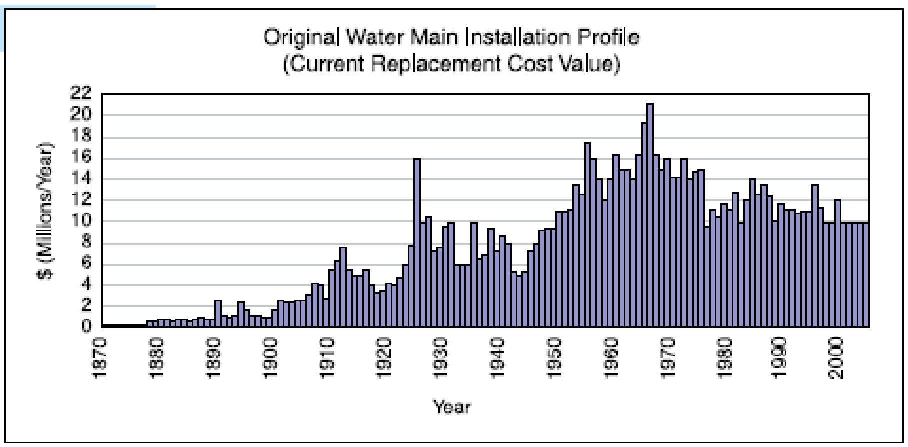
Source: National City Water Survey 2005, The United States Conference of Mayors Urban Water Council, November 15, 2005

Note: Multiple methods used by each city so categories do not sum to 100%.

Projected National Drinking Water Capital Investment (20-Year Horizon)
(millions of 2003 $)

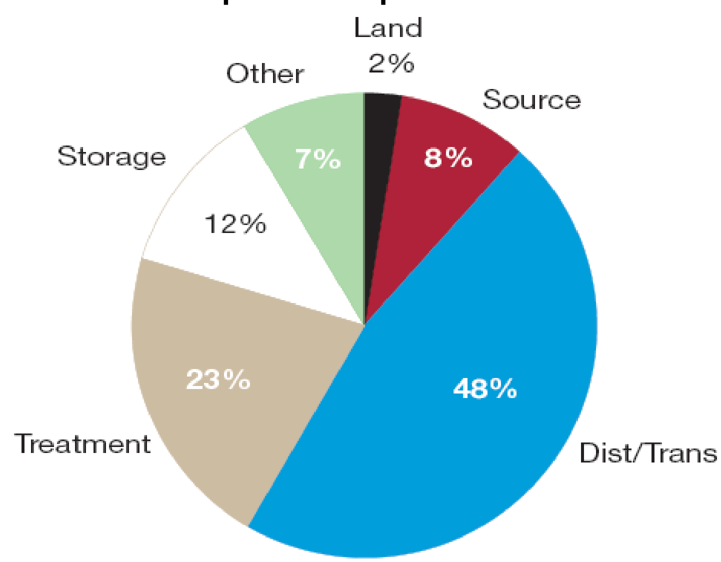
System Size and Type	Distribution and Transmission	Storage	Source, Treatment, Other	Total
Large Community Water Systems (serving over 50,000 people)	$89,779.9	$6,994.5	$26,077	$122,851.7
Medium Community Water Systems (serving 3,301 to 50,000 people)	$73,454.4	$9,473.3	$20,090	$103,017.4
Small Community Water Systems (serving 3,300 and fewer people)	$18,624.3	$6,263.8	$9,283	$34,171.5
National Total	$183,631.1	$24,842.2	$68,288	$276,761.5

Source: 2003 Drinking Water Infrastructure Needs Survey and Assessment, EPA, 2005



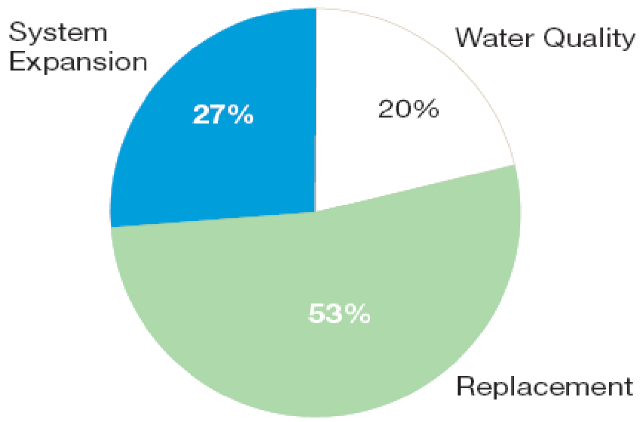
Source: Water Infrastructure at a Turning Point: The Road to Sustainable Asset Management, AWWA, 2006

Capital Expenses

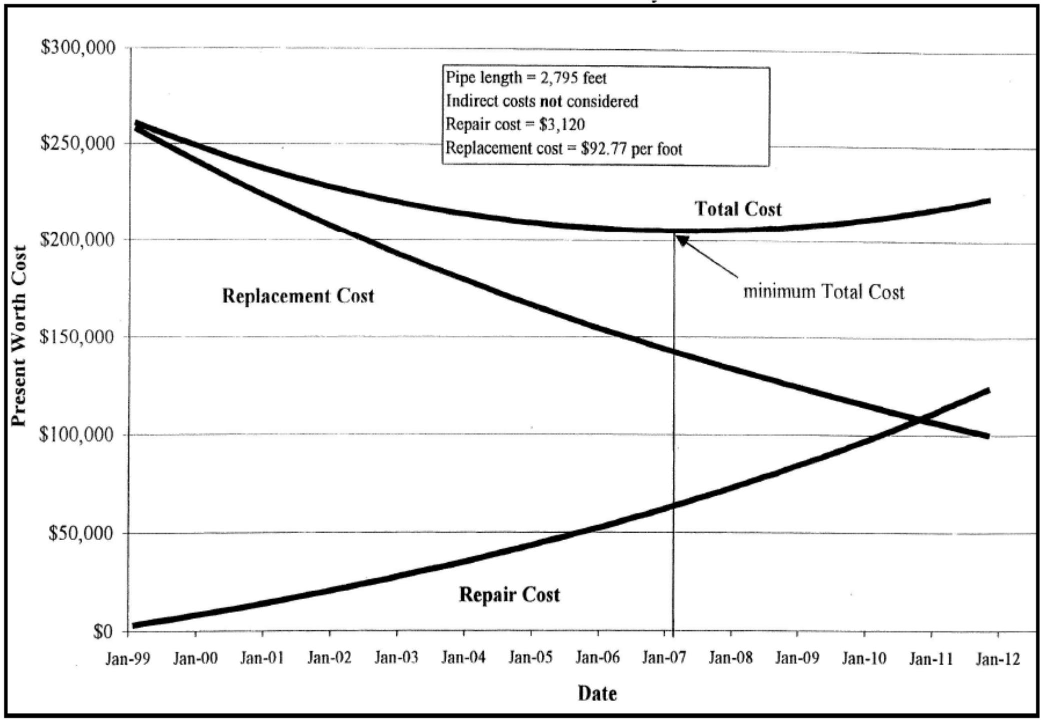


Source: Community Water System Survey, EPA, 2000
Note: Graphic limited to publicly owned PWSs

Making the Decision to Repair or Replace



Source: 2003 Drinking Water Infrastructure Needs Survey and Assessment, EPA, 2005



Source: Deteriorating Buried Infrastructure Management Challenges And Strategies, AWWS Co., 2002

Element	Typical Useful Life (Years)	Cost (2006 $)
Pipe (1 ft, 8 in ductile iron, installed)	12 - 40+ [1]	$32 - 60
Metal Storage Tanks (100,000 gallon)	50+	$125,000+
Pump (200 - 400 GPM, 100 hp)	10+	$20,000
Double-Check Valve (4 inch)	15	$200 - $300
Meter (residential)	15	$75 - $100

Note [1] - Limited period of record, likely much longer.

Every asset has a useful life after which it must be replaced but there is also a significant window of time when repair may be more cost efficient.

Managing Water Loss – Two Components

- **Water Loss**, the volume left after subtracting all authorized billed and unbilled water consumption from the system input volume, includes
  - **Real losses**, physical loss of water from the distribution system (waste of water resource)
  - **Apparent losses** or "paper" losses include customer meter inaccuracy, all manner of billing accounting errors and unauthorized use (source of lost revenue to PWS)

Unaccounted For Water

	System Service Population								
	≤ 100	101-500	501-3,300	3,301-10,000	10,001-50,000	50,001-100,000	100,001-500,000	> 500,000	Average
Percent of Total Water Produced	0.3	3.4	9.1	11.4	9.1	9.9	6.7	7.9	5.6
Confidence Interval (+/-)	0.3	2.9	3.2	2.7	1.7	1.9	1.5	1.0	1.3

Source: Community Water System Survey, 2000, EPA

Note: Survey response generated using problematic historical calculation methodology.

Responsibilities of a Distribution System Operator

- Balance energy consumption with water production needs
  - Requires combination of storage and direct pumping
- Fill storage daily when water is in surplus
  - Without overflowing storage facilities
- Cycle water in storage facilities to ensure adequate mixing
  - e.g., storage cannot just be kept full
- Anticipate unusual water withdrawal patterns
  - Weather-related or due to planned events
  - System cannot be caught with storage drawn down
- Maintenance of adequate pressure and quantity in all parts of system
  - 24 hours per day, 7 days per week
  - Requires coordination throughout the PWS and
    - Planned treatment and distribution construction,
    - Temporary outages of water sources,
    - Routine flushing or valve exercising,
    - Emergency events such as fire fighting, main breaks, etc.
- Maintain adequate disinfectant residual

Professional Standards and Practices

Example Standards

Element	Standard	1st edition
Pipe	Reinforced Concrete Pressure Pipe	1947
	Cement Lined Ductile Iron Pipe and Fittings	1985
	Ductile-Iron Pipe, Centrifugally Cast	1965
	Ductile Iron and Gray Iron Fittings	1951
	Flanged Ductile-Iron Pipe with Ductile-Iron or Gray-Iron Threaded Flanges	1975
	Cement-Mortar Protective Lining and Coating for Steel Water Pipe	1941
Valves	Wet-Barrel Fire Hydrants	1959
	Butterfly Valves	1954
	Backflow Prevention Devices	1969
Meters	Cold-Water Meters - Displacement Type	1921
	Cold-Water Meters - Turbine Type	1923

Example Practices

Element	Standard	1st edition
Pipe	Disinfecting Water Mains	1947
	Distribution system Requirements for Fire Protection	1989
	PVC Pipe - Design and Installation	1980
	Polyethylene Pipe - Design and Installation	2006
Storage	Disinfection of Water Storage Facilities	1980
	Painting Steel Water-Storage Tanks	1964
Valves	Air-Release, Air/Vacuum & Combination Air Valves	2001
	Distribution Valves: Selection, Installation, Field Testing, and Maintenance	1996
All	Water Audits and Leak Detection	1990

Note: Above examples drawn from AWWA Standards and Practices. There are also NSF, ANSI, ASM, and other professional standards that apply to engineering, construction, materials, and maintenance of distribution system infrastructure. All standards and practices are regularly reviewed and updated by the responsible organization.

Implementation of Best Management Practices

Distribution System Best Management Practice	Percent of Systems Implementing BMPs							
	≤ 100	101-500	501-1,000	1,001-3,300	3,301-10,000	10,001-50,000	50,001-100,000	> 100,000
System mains installed in accordance with state regulations	63%	78%	85%	93%	95%	100%	100%	100%
Disinfection of newly installed water mains	51%	64%	80%	82%	94%	98%	86%	100%
Disinfection of water mains following repair after breakage	46%	57%	64%	70%	80%	89%	86%	100%
System maintains an acceptable system pressure at all times	68%	70%	77%	83%	94%	99%	100%	100%
Water main flushing program	36%	41%	69%	60%	79%	90%	86%	100%
Water distribution tanks are designed according to state regulations	65%	73%	86%	90%	92%	98%	100%	100%
Water distribution tanks are routinely inspected and maintained	45%	49%	68%	98%	82%	96%	86%	100%
Water distribution system storage tanks are routinely cleaned	34%	41%	55%	50%	57%	70%	71%	50%
Water distribution system storage tanks are disinfected	50%	62%	78%	74%	89%	98%	86%	100%
Water cycles through storage tank on frequent basis	72%	79%	84%	79%	77%	89%	86%	100%
Distribution system maintenance plan	19%	27%	42%	39%	61%	73%	86%	100%
System maintains a disinfection residual[1]	42%	48%	56%	67%	76%	82%	86%	100%

Source: ASDWA Survey of Best Management Practices in Community Ground Water Systems, 1998 (based on data from 1995-1996, 36 states)
Note[1]: Groundwater systems are frequently undisinfected systems.

NAS Report - Recommendations

- NAS identified priority issues for distribution system infrastructure
  - Cross connection control and backflow prevention
  - Assuring controls are in place to prevent chemical and microbial contamination of distribution system materials and drinking water during main breaks and during the installation, rehabilitation, and repair of water mains and appurtenances.
  - Preventing contamination of storage
- Encourage management of premise plumbing (e.g. through building code improvements/enforcement).
- Ensure adequate training of distribution system operators.